# Environmentally Preferred Alternatives to Methylene Chloride for Paint Stripping

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## ABSTRACT

Chemical strippers (e.g., methylene chloride) traditionally have been used to remove paints and coatings. These chemical strippers have many advantages but they are potentially harmful to worker health and safety and the environment. Additionally, compliance with future clean air regulations (NESHAP) may make their use very costly.

In response to an ESOH Technology Need Survey conducted by the Human Systems Center (HSC/XRE), the Air Force Research Laboratory evaluated environmentally preferred chemical alternatives for methylene chloride based chemical paint strippers to address a need submitted by the Ogden Air Logistic Center (OO-ALC) Commodities Directorate, Landing Gear Division located at Hill AFB. ARFL initiated and completed the identification and evaluation project for a commercially available, environmentally friendly, method of removing the paint from aircraft landing gear. Although mechanical paint stripping technologies are the preferred pollution prevention practice to replace chemical paint strippers; the complex geometry of the landing gear components required that environmentally friendly chemical paint strippers be investigated as a potential "drop-in" replacement for OO-ALC and other Air Force applications. The study concluded that an environmentally friendly alternative chemical paint stripper is currently available to meet OO-ALC's need (Ecolink SAFE-STRIP). The addition of recommended process improvements combined with the material substitution will increase the efficiency of OO-ALC's operation and will provide an economically feasible while further reducing environmental impacts.

## INTRODUCTION

This is a case study of how a replacement solution for phenolic methylene chloride was identified and evaluated using an eight step process.

The study was limited to dip tank/immersion paint stripping processes in use at OO-ALC. Therefore, the findings presented below are not directly transferable to other types of applications, although the steps used to identify and evaluate the alternatives can be applied to any material substitution.

The following eight step process was used.

- Step 1 - Determine the Process Boundaries
- Step 2 - Identify Potential Commercial-Off-The-Shelf (COTS) Alternatives
- Step 3 - Down-select the Field to the Top 10 Alternatives
- Step 4 - Evaluate the Technical Performance of the Selected Alternatives
- Step 5 - Compare the Best Alternative to the Current Process for Environmental Impacts and Cost Benefit Analysis
- Step 6 - Identify Process Improvements
- Step 7 - Evaluate Best Alternative with Potential Process Improvements
- Step 8 - Implement or Recommend Alternative Course of Action

**Step 1 - Determine the Process Boundaries**

Process boundaries are defined as the material compatibility requirements, maximum processing time, quality requirements, existing process equipment, and environmental health and safety constraints. The process boundaries surrounding OO-ALC's operation set the focus and direction for the remaining steps. At OO-ALC the nature of the work determined that all potential alternatives must be compatible with aluminum, stainless steel, and magnesium; remove a minimum of 80% the paint within 30 minutes; and be suitable for use in a dip tank. In addition, the paint remover could not contain phenol, phenol derivatives, or chlorinated solvents which would have an adverse effect on the health of facility personnel.

Secondary process considerations where also determined to have a tangible cause and effect relationship on the overall operation. For example the methylene chloride tanks are currently operated at room temperature (cold). If the alternative paint stripper must be heated to work effectively, then heating elements must be used in the dip tanks. In addition, the air emissions from the alternative paint strippers could potentially rise faster then the methylene chloride stripper bypassing the air pollution control equipment and causing potentially high levels of worker exposure, maintenance problems with overhead equipment, and regulatory concerns. Boundaries must be defined to understand the scope or "universe" of the research effort conducted to identify potential alternative paint strippers.

**Step 2 - Identify Potential Commercial-Off-The-Shelf (COTS) Alternatives**

If vendors are selected randomly, companies with potential solutions may be easily overlooked, especially smaller companies. This may force additional expensive laboratory testing to be repeated because all randomly identified solutions failed to meet the final testing requirements. Thorough identification of all potential alternatives can greatly reduce the risk of repeating a project, even if all identified solutions fail, because the defined universe of vendors were all investigated.

For OO-ALC's landing gear paint stripping operation three sources of information were identified and used to define the "universe" of chemical paint stripper manufacturers: Department of the Air Force, Military Qualified Products List Under Military Specification MIL-R-83936B, "Remover, Paint, Tank Type: For Aircraft Wheels, Landing Gear Components and Other Aircraft and AGE Components;" WWW BigBook Yellow Pages on the Internet; and the Tri-Services Pollution Prevention Technical Library, Paint Removal, listed on the EPA's Enviro$ense home page on the Internet. Collectively, 142 unique vendors were identified. These three sources were considered comprehensive enough to validate a non-discriminatory selection process. Vendors were contacted by telephone and interviewed to obtain product information and determine product applicability to OO-ALC's process boundaries (e.g., designed for use in a dip tank).

**Step 3 - Down-select the Field to the Top 10 Alternatives**

Financial constraints restricted the research effort from conducting detailed product evaluations and laboratory testing of all alternatives identified. Therefore, selection criteria ranging from broad in nature to more restrictive were necessary to limit the field of alternatives.

Two levels of selection criteria were used to down-select the list of identified alternatives for OO-ALC from 142 unique vendors to the top 10 alternatives. The "first-cut" selection criteria was broad in nature and based on the primary process boundaries identified in Step 1. After the "first-cut" only 14 alternatives met the selection criteria and were chosen for further (level 2) evaluation and comparison ranking. The following four criteria were used to rank the 14 products based on the primary and secondary process boundaries identified in Step 1.

- *Regulatory and Environmental Policy Drivers* - Quantified by percent of total composition: NESHAP, EPA 17 Chemicals, ODC, SARA III, and AFMC 24.
- *Physical Characteristics* - Flash Point, Vapor Density, VOC Content, Specific Gravity, pH, and Viscosity.
- *Occupational Safety and Health* - Health Hazard (Acute & Chronic), Carcinogenicity (NTP, IARC, OSHA), Exposure Limit (ACGIH TLV, OSHA PEL), and PPE Required.
- *Economic/Process Factors* - Cost per Gallon, Estimated Longevity, Recyclability, Tank Type (Hot or Cold), Dwell Time, and Paint Residue (Small Pieces or Large Sheets).

Point values were assigned to each area and weighted equally to rank the 14 alternatives. The current phenolic methylene chloride paint stripper was also evaluated to bench mark the ranking. The ten alternative paint strippers with the highest scores were selected for laboratory testing. The top 10 alternatives selected and the control are listed in Table 1.

**Step 4 - Evaluate the Technical Performance of the Selected Alternatives**

Validating the material compatibility and performance characteristics of an alternative prior to full-scale implementation into the process can prevent serious damage to expensive parts and processing equipment, as well as, limit the capital purchase cost of the alternative product for testing. Laboratory testing can be effectively used with metal coupons to "roughly" simulate process demands.

For OO-ALC the top ten alternative paint strippers were tested in a laboratory using metal coupons and condemned aluminum aircraft wheel segments to determine material compatibility and paint stripping efficiency. Tests included Flammability, Viscosity, Longevity, Corrosion, Paint Stripping Efficiency, and Hydrogen Embrittlement. The laboratory procedures for each test were modified to best represent the operating conditions at the OO-ALC landing gear paint stripping operation. The corrosion and paint stripping efficiency tests were completed twice as part of the longevity test; once with new solution as received from the vender (denoted as "NS") and once with solution that was contaminated for 90 days with a 30% paint loading (denoted as "LS"). The purpose of conducting the Longevity test was to determine if the paint strippers lost their effectiveness within a 90-day period and to ensure that the material compatibility properties did not change with time. Table 1 summarizes the "Pass/Fail" results.

**Table 1: "Pass/Fail" Laboratory Testing Summary Results**

| | Flammability | Viscosity | Corrosion | | Paint Stripping Efficiency | | Hydrogen Embrittlement | Overall "Pass / Fail" |
|---|---|---|---|---|---|---|---|---|
| | | | "NS" | "LS" | "NS" | "LS" | | |
| Ecolink SAFE-STRIP | F | P | P | P | P | P | P | F |
| ALKOSURF 718 | F | P | P | P | F | F | P | F |
| Gage Stingray™ 554 | P | F | F | F | P | F | P | F |
| THERMACLEAN® 095-0048 | P | P | P | P | F | F | P | F |
| Savogran S.I. No. 3 | F | P | P | P | F | F | P | F |
| Savogran S.I. No. 8 | F | P | F | P | F | F | P | F |
| Brulin Safety Strip 1000 | P | P | F | F | F | F | P | F |
| Brulin Safety Strip HT | P | P | P | F | F | F | P | F |
| Calgon SPS-540T | P | P | F | F | F | F | P | F |
| Calgon SPS-570-81 | P | P | F | F | F | F | P | F |
| *CEE BEE A-235 (Control)* | P | P | P | P | P | P | P | P |

Based on the acceptance criteria developed at the start of this project, none of the 10 alternatives paint strippers tested successfully passed all of the criteria.

Out of the ten alternative paint strippers tested, one product, Ecolink SAFE-STRIP successfully met all of the criteria except one; the Flammability Test. Ecolink SAFE-STRIP failed one out of four of the flammability test trials by burning for one second longer than the acceptance criteria. Upon review of the preliminary test results it was concluded that Ecolink SAFE-STRIP should be further evaluated for implementation with the understanding that a process safety hazard may exist.

**Step 5 - Compare the Best Alternative to the Current Process: Environmental Impact and Cost Benefit Analysis**

The next step was to develop a direct comparison between the best alternative from Step 4 (assuming it passed all minimum laboratory testing requirements) and the current process. The direct comparison includes qualitative data from the laboratory testing to estimate waste generation rates and process characteristics of the alternative. In general, direct comparison includes all detail available and relevant to the actual process. Good starting points are: material safety data sheets, and the primary and secondary process boundaries identified in Step 1. A direct comparison of all environmental impacts helps ensure that the environmental problems are being reduced or eliminated, as opposed to simply being shifted to a different media (air, water, land).

A cost benefit analysis is a proven tool for evaluating the feasibility of implementing any type of material or process change. At a minimum, a cost benefit analysis identifies the estimated capital cost, the change in annual operating cost, the annual savings or loss, and the payback period. A combination of the capital cost and the payback period are generally used as the financial indicators to approve or disapprove a proposed alternative.

An abbreviated summary of the direct comparison of the phenolic methylene chloride stripper (CEE BEE A-235) and the top alternative selected for OO-ALC (Ecolink SAFE-STRIP) are presented in Table 2.

**Table 2: Summary of Material Substitution Impacts on OO-ALC's Landing Gear Paint Stripping Operation**

| Driver | CEE BEE A-235 (Current Process) | Ecolink SAFE-STRIP (Direct Material Substitution Only) | Net Effect |
|---|---|---|---|
| HAP | 86,724 lbs. | 0 lbs. | 100% Reduction |
| VOC | 0 lbs. | 79,155 lbs. | 100% Increase |
| EPCRA §313 | 122,400 lbs. | 661,123 lbs. | 440% Increase |
| RCRA - Sludge | 43,500 lbs. | 707,465 lbs. | 1,526% Increase |
| RCRA - PBM | 350,000 lbs. | 350,000 lbs. | No Effect |
| AFMC 24 | 121,176 lbs. | 0 lbs. | 100% Reduction |
| Capital Cost | NA | $507,026 + OSHA Upgrades | NA |
| Operating Cost | $875,182 | $2,748,482 | 214% Increase |
| Annual Savings | NA | ($1,873,007) | NA |
| Payback Period | NA | No Payback | NA |

Replacing the entire 22,000 gallons of paint stripper every 90 days dominated as the main operating cost driver for the process. Assuming, the life-span of Ecolink SAFE-STRIP proved to be 180 days or 1 year the expected increase in annual operating costs decreases dramatically. Although the main goal of eliminating phenolic methylene chloride and corresponding hazardous air pollutant emissions from the process was accomplished, additional environmental impacts such as VOC emissions, TRI chemical releases, and increased hazardous waste generation were realized.

**Step 6 - Identify Process Improvements**

Performing a material substitution or process change may open new opportunities for process efficiency and pollution prevention that were not previously available. The addition of process improvements can often make an environmentally preferred alternative more financially attractive and environmentally better. One method of identifying areas for improvement is to identify all of the areas having a "negative" effect on the operation from the direct comparison developed in Step 5.

At OO-ALC, process improvements were explored to offset the economic burden and reduce increased generation of VOC emissions, TRI chemical releases, and hazardous waste. Seven process improvements were identified; four of which had sufficient data to re-evaluate performing the material substitution. They are as follows:

- *In-Process Recycling - Vacuum Distillation* - In-process recycling of Ecolink SAFE-STRIP through vacuum distillation will eliminate the need to replace the solution, indefinitely, in turn reducing the volume of hazardous waste generated.
- *Reduce Liquid Surface to Air Ratio* - Reducing the evaporation rate will decrease the amount of paint stripper lost to direct emissions and decrease the demand for steam to heat the tanks. One method is to add hexagonal polypropylene floats (called Hexies) on the surface of the paint stripper. The vendor of Hexies states that field evaporation tests have demonstrated up to a 70% reduction in fluid loss from evaporation.
- *Implement a Closed Loop Rinse Cycle* - It is estimated that approximately 18,480 gallons of raw material would be lost to the rinse cycle per year; requiring an annual replacement value of $388,080. In addition, the loss of paint stripper is directly proportional to the amount of VOCs lost from the total process. It is estimated that 37.5 tons of VOCs will be transferred to the Industrial Wastewater Treatment Plant (IWTP) from the rinse cycle (equivalent to 97% of the total estimated VOC emissions from the paint stripping operation). A closed loop rinse cycle could eliminate a maximum of 97% of the total VOC emissions from the operation, as well as, reduce the amount of water used and the burden on the IWTP.
- *Implement a Sludge Management System* - A Sludge Management System would automatically remove the sludge from the tank bottoms on a daily basis and return the paint stripper back to the process tank. The remaining paint sludge would be dry (containing less than 1% paint stripper).

**Step 7 - Evaluate Best Alternative with Potential Process Improvements**

If sufficient data is available to estimate the impact of the process improvements on the overall process it is recommended to repeat the environmental and cost benefit analysis. Specifically in the case of material substitutions, additional process improvements that can be implemented simultaneously with the alternative can often improve the environmental and financial benefits to the point of changing a disapproval to an approved status.

The impact of implementing the process improvements identified in Step 6 with the substitution of Ecolink SAFE-STRIP for CEE BEE A-235 at OO-ALC resulted in an improved financial outlook (no payback period to an estimated 5.3 year payback period) and reduced environmental impacts from the total operation (99% in most areas of concern). Table 3 summarizes the material substitution impacts on OO-ALC's landing gear paint stripping operation with process improvements implemented.

**Table 3: Summary of Material Substitution Impacts on OO-ALC's Landing Gear Paint Stripping Operation with Process Improvements**

| Driver | CEE BEE A-235 (Current Process) | Ecolink SAFE-STRIP (Direct Material Substitution Only) | Ecolink SAFE-STRIP with Process Improvements | Net Effect with Process Improvements |
|---|---|---|---|---|
| HAP | 86,724 lbs. | 0 lbs. | 0 lbs. | 100% Reduction |
| VOC | 0 lbs. | 79,155 lbs. | 1,258 lbs. | 100% Increase |
| EPCRA §313 | 122,400 lbs. | 661,123 lbs. | 1,222 lbs. | 99% Reduction |
| RCRA – Sludge | 43,500 lbs. | 707,465 lbs. | 8,969 lbs. | 79% Reduction |
| RCRA – PBM | 350,000 lbs. | 350,000 lbs. | 350,000 lbs. | No Effect |
| AFMC 24 | 121,176 lbs. | 0 lbs. | 0 lbs. | 100% Reduction |
| Capital Cost | NA | $507,026 + OSHA Upgrades | $672,506 + OSHA Upgrades | NA |
| Operating Cost | $875,182 | $2,748,482 | $748,354 | 14% Reduction |
| Annual Savings | NA | ($1,873,007) | $126,828 | NA |
| Payback Period | NA | No Payback | 5.3 years Excluding OSHA Upgrades | NA |

**Step 8 - Implement or Recommend Alternative Course of Action**

The last step of the eight step identification and evaluation process was to review the benefits and limitations of the options presented and recommend a course of action to either implement the alternative or to investigate new methods to reduce the environmental health and safety impacts associated with the operation.

Based upon the findings of the OO-ALC landing gear paint stripping project the next steps are two-fold; a short-term and long-term. The short-term objective is to further evaluate Ecolink SAFE-STRIP on a 500-gallon scale up basis and to evaluate identified process improvements and required process changes. Fine tuning the process design for implementing Ecolink SAFE-STRIP will ensure a short-term solution for eliminating hazardous air pollutants, methylene chloride, from the operation in the event that the Aerospace NESHAP revisions are promulgated in the next several years. Following the results of scale-up testing the implementation of Ecolink SAFE-STRIP may prove to be more economically viable, therefore, warranting implementation.

The long-term objective is to develop a paint stripper that will both meet or exceed OO-ALC's performance requirements and be cost effective to implement and operate. To meet the long-term objective the following options are available:

A) conduct basic research to develop an environmentally friendly paint stripper that meets OO-ALC's performance requirements and is cost effective;

B) repeat the approach of evaluating commercial-off-the-shelf solutions can be on a 5 year basis to resample the market for new environmentally friendly paint strippers;

C) develop improved corrosion barriers to eliminate the need to paint landing gear components, therefore, phasing out the need for a landing gear paint stripping operation; and/or

D) develop improved non-destructive inspection technology to eliminate the need to remove the paint from the landing gear components for the sole purpose of performing non-destructive inspection.

## SUMMARY

A successful short term solution was identified through AFRL's efforts to meet Ogden ALC's goal of replacing methylene chloride as a chemical paint stripper in the landing gear overhaul facility.

As in any case when making a material substitution there are trade-offs. This is very true in the case of chemical paint strippers. While phenolic methylene chloride is a known carcinogen, hazardous air pollutant, and identified as one of the Environmental Protection Agency's top 17 (EPA-17 Chemicals) chemicals for elimination; it strips paint fast, lasts for several years without having to be replaced, and only costs about $10 a gallon.

On the other hand, new environmentally friendly chemical paint strippers do not contain known carcinogens, hazardous air pollutants, or EPA-17 targeted chemicals. The drawback is that they tend to remove paint at slower rates, have shorter life-spans, and cost between $15 - $35 per gallon or higher depending on the formulation. In addition, environmentally friendly chemical paint strippers are largely comprised of volatile organic compounds (VOCs) that have a higher rate of evaporation the traditional phenolic methylene chloride blends.

Based on AFRL's findings a viable solution to OO-ALC landing gear paint stripping operation was successfully identified. With the use of process modifications, secondary in-process recycling equipment and sludge management technologies, alternative environmentally friendly chemical paint stripper are clearly the better environmental choice. In addition, applying total cost accounting to the landing gear paint stripping operations economic evaluation would further increase the projects financial feasibility through the reduction in recurring environmental costs.